but the feeding-polyp, which lies in the centre of the under-side, is hidden by the oval float in the middle of the body.

Of all the Medusæ considered, Velella is the only one which floats on the surface of the sea, the whole upper surface of the body, or that shown in the figure, being exposed to the air. From this fact, as well as from certain rhythmical motions made by Velella, it is not improbable that the respiration is in part aerial in this Medusa, as has been already pointed out by Dr. Carl Chun. To facilitate this mode of respiration, and to bring the air into the interior of the body, there are tubes, called tracheæ, communicating with the cavity of the float, through which air is taken in and gas expelled by the movements of the body. At the same time there is also an abundant opportunity for aerial respiration through those parts of the body which are always exposed to the air.

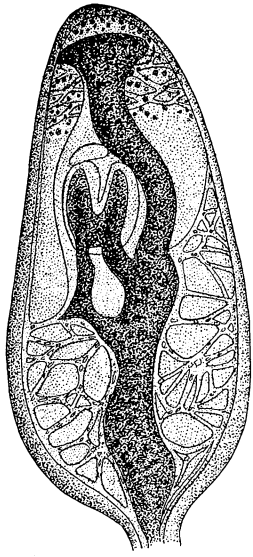
NOTES ON THE HABITS OF SOME AMBLYSTOMAS.

BY O. P. HAY.

MY observations on the habits of the Amblystomas have been made almost wholly on the three species, *A. microstomum, A. tigrinum, and A. punctatum.* These species have received respectively the vernacular names, small-mouthed salamander, tiger salamander, and spotted salamander. All three are quite abundant about Indianapolis, the *microstomum* most of all; and it is this that I have been enabled to study most carefully. Unless otherwise noted, my remarks will refer to this species. It will be most convenient perhaps to begin with the life of the individual; first of all with those events which make provision for the life of the individual.

The eggs of the small-mouthed salamander are laid very early in the spring, as soon as the thick ice of the winter is gone, or even before it is gone. During the present year I found eggs of this species at noon of March 3. They had probably been laid during the preceding night. They were attached singly

PLATE XXVII.



GONOSAC OF ATRACTYLOIDES.

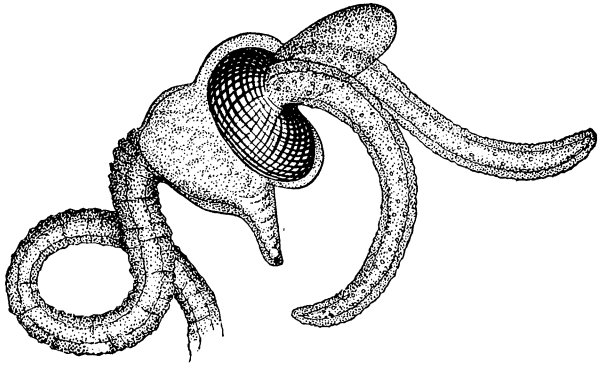


FIG. 12 *a.*—*Athorybia californica.*

and in bunches of various sizes to blades of dead grass and to sticks under water. I have also seen them strung along on the bottoms of shallow ditches, as if they had been deposited by the female while crawling about. I have reason to suspect that eggs had been laid in the same ponds at an earlier date. It is also certain that oviposition continued at least as late as March 22.

The eggs are quite small, the diameter being about 2 mm. Each egg is surrounded with a capsule of a clear gelatinous substance, by which it adheres to other eggs and to objects in the water. This mass of gelatinous matter has a diameter of from 6 to 9 mm. It is made up of two principal layers separated from each other by a very thin layer, and from the yolk by apparently two other very thin layers.

How the eggs are fertilized by the male I have not observed; but it is probably much as in the case of *A. punctatum*. Some eggs strewed by a female over a brick in an aquarium failed to develop, doubtless because they were not fertilized. All the eggs found on the third of March had begun segmentation, and it was not long before the outlines of the embryo became visible. The changes passed through by the embryo cannot be here detailed. Very early cilia are developed on the outer surface, and the embryo begins slowly to revolve within the gelatinous envelope. When it is 8 mm. long it lies coiled within the envelope, and may be seen to possess short buds to represent the gills and the "balancers." About the 28th of March, some of the eggs were so far advanced that on being handled the tadpoles slipped out of the gelatine, and swam about in the water. Already, however, there were more advanced larvæ swimming about in the pond, which I could not distinguish as different. The eggs from which the latter originated may have been laid earlier; but it seems quite certain that some eggs develop more rapidly than others. Many of the eggs which I had more particularly under observation did not hatch until April 10th. At the time of escape from the egg the young are about 10 mm. in length. They are of a bright olive-green color, with indications of squarish blotches along the back. There is a broad fin running along the back and around the end of the tail to the vent. Three

little gills stand out on each side of the neck, and on these may be seen a few rudiments of lateral filaments. The fore-legs exist as the merest little buds. The head is rounded in front, and the mouth is below, features due to the yet persisting cranial flexure. It is doubtful if the mouth is yet perforated. The heart may be seen beating at a lively rate, and the blood coursing through the gills. During the earliest period of its free life, currents of water are directed over the gills and the body by the action of the cilia; but soon currents may be seen to enter by the nostrils and to make their exit through the gill slits. After this the ciliary action becomes feebler, and at length ceases. When the larvæ have attained a length of about 12 mm. [one-half inch] the lateral filaments of the gills have become distinct, and may be seen arranged in two rows on the under side of the main stem. There are four to six filaments in each row. The mouth is now nearly terminal, and microscopic sections reveal the existence of premaxillary, vomerine, dentary, and splenial teeth. Nothing was found in the stomach of this sectioned specimen, but it may have been an unsuccessful hunter. Toward the last of April, the larvæ have reached a length of from 15 to 18 mm. The anterior limbs are conspicuous, and show each two short toes. The posterior limbs are present as elongated processes. The so called "balancers" have shrunken somewhat, and give evidences that they will soon be lost. The tadpoles are more inclined to lie at the bottom of the water when resting than to cling to the sides of the vessel.

From the time of hatching up to this stage the "balancers" are conspicuous organs. They are attached just behind the mouth on each side, and resemble a base ball bat. They are said by Professor S. F. Clark[1] to function as supports for the larvæ when they fall to the bottom of the pond during the period while the fore-legs are still undeveloped. I doubt if they are of much use in this way. In the aquarium they spend much of their time sticking to the walls, and it is by means of these organs that they suspend themselves. They are by no means "suckers," and it is doubtful if they secrete a sticky fluid, as the

[1] Studies from Biolog. Lab. Johns Hopkins University, No. II., 1880.

PLATE XXVIII.

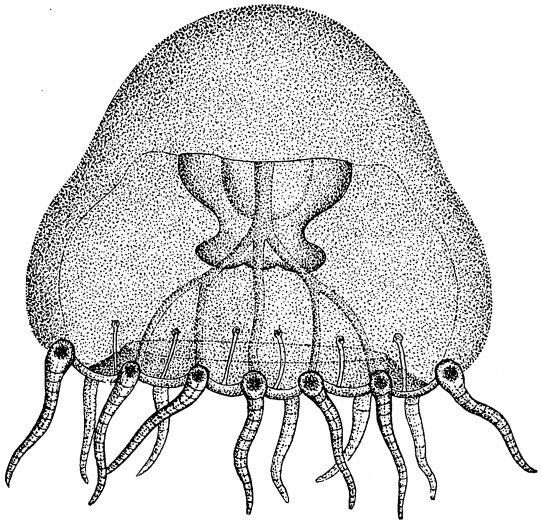


FIG. 11.—WILLIA.

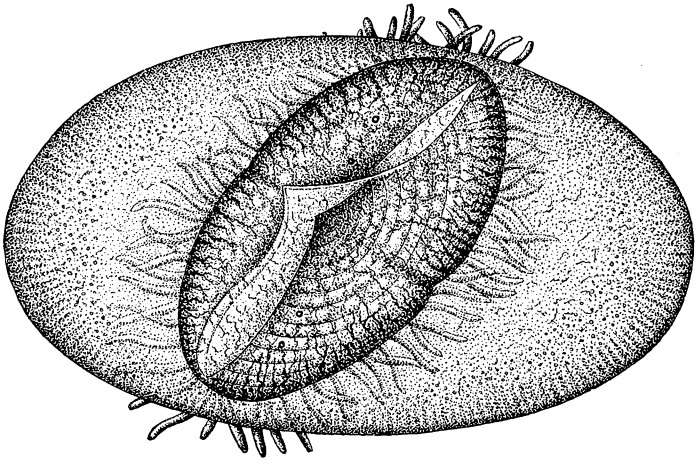


FIG 13.—*Velella meridionalis.*

organs of adhesion of the frog are said to do. In microscopic sections the epidermal cells near the tip of the organ appear each to project into a point, so that the whole surface is roughened somewhat. Since all objects in the water soon become covered with a thin layer of slime, the holders will adhere to this with sufficient force to suspend a little creature which is of nearly the same specific gravity as the water. When they are put into a clean glass or tin vessel, it is with great difficulty that they can succeed in attaching themselves to the perpendicular side. After making many unsuccessful efforts they sink to the bottom seemingly exhausted, and lie quite as often on their sides as on their bellies. When the holders have been lost, I have observed the larvæ to suspend themselves to the walls by means of their toes, or by a single toe.

While they are adhering to objects by means of the holders one may, under a lens, and with the point of a fine forceps, loose one holder and allow the tadpole to hang by the other alone. One may then touch the forceps to the adhering holder, and succeed in dragging the little animal hither and thither through the water.

Larvæ of the length of 15 mm. had their intestines filled with the remains of small animals. These consisted mostly of entomostracous crustaceans, such as *Daphniidæ*, *Cyclops*, and the like; but there were also found portions of the young of *Crangonyx* and *Asellus*, and of the larva of some beetle. The ponds which harbor these amphibians literally swarm with minute animal life, and the tadpoles are active, hungry, and fierce.

When the tadpoles have become about 25 mm. long, they may occasionally be seen to come to the surface for air. This shows that the lungs are becoming functional. A bubble of air is expelled by the mouth just as, or before, the tadpole reaches the surface; a portion of fresh air is probably inhaled; and the tadpole hastens to the bottom, as if alarmed at having exposed itself.

The changes from this time on until near the time of metamorphosis consist principally in increase in size and further development of the limbs. A tadpole two inches long and full-grown may be briefly described. Those who are familiar with figures

of the axolotl will need little additional description. The body is catfish-shaped. A high membranous fin begins on the back just behind the head, and continues around the tail to the vent. Fore limbs with four fingers each, and hinder limbs with five toes each, are present. On each side of the head are three gills, of which the upper is the longest, and the lowest the shortest. The main stem of each gill bears on its lower edge a fringe of filaments in which the blood is brought into close contact with the water. The upper surfaces of the head and body are olive, mottled and speckled with black; the whole lower surface is white.

Reference has been made to the food of the tadpoles in their native haunts. Last season I obtained a large number of the young of *A. microstomum* and kept them for some time in a glass jar. Soon I found that their gills were disappearing, from which circumstance I concluded that they were transforming. Soon, however, it was also seen that some of them were also losing their legs; whereupon I began to watch proceedings a little more closely. One was seen to seize another by a leg, and a struggle followed for the possession of the member. It was plain that they were devouring one another alive. Not knowing what else to do I procured some slender angle-worms, and breaking them in pieces threw them into the water. Soon a tadpole approched a section of the worm and began to show interest in it. Presently with a sudden leap he seized the morsel and shook it violently, as if he expected resistance. By sudden snaps and gulps the worm was soon worked down the tadpole's throat. A tadpole would in this way swallow a piece of worm of nearly his own diameter and an inch or more in length. After this my specimens were abundantly supplied with this diet, the cannibalism ceased, and the larvæ increased rapidly in size. When they are not supplied with food they are able to endure hunger for a long period, but they do not grow. If one wishes to rear them in aquaria, one may easily strain out the Entomostraca of pond water, and thus furnish them with acceptable food. On the bottom of an aquarium in which a number of freshly-captured nearly-grown larvæ had been kept for a few days, were found numbers of the shells of a small species of *Planorbis* or related genus of mollusks.

Toward the last of May my specimens began to undergo their metamorphosis. The gills began to suffer absorption and the broad tail fin to disappear. They came oftener to the surface for air, and they spent a good deal of their time floating on the water. When the tadpole took in air, he would float horizontally. As the oxygen of the inhaled air was converted into carbonic acid, and this in its turn given off into the surrounding water, the little animal's body grew heavier and he began slowly to sink, the tail going down first. To counteract this a few feeble movements would be made, but still down he would go. At last by a strong effort the animal would bring his head to the surface, take in air, and then quickly regain the horizontal position.

At this time the young showed also a strong inclination to leave the water. They would crawl up on sticks and stones and remain there. When in a glass vessel they would sometimes be found climbing up the perpendicular side, two or three inches above the water.

The time of completing the change is about the first of June, although some specimens may have completed it sooner. As it progresses, the tail becomes more terete and the whole body slenderer and less bulky. The general color above becomes black, while here and there white specks appear; and the animals are soon small models of the full-grown adults.

When my specimens had transformed, about fifty of them were put into a box in which was a sod about a foot square. Into this they immediately disappeared, and burrowed through and through it. When it was allowed to become dry, they would be found under it, where a little moisture remained. When it was thoroughly wet, they would appear at the surface among the grass blades and roots. At length it was allowed to become thoroughly dry, and the salamanders perished. Doubtless, however, many of them had escaped by crawling up the sides of the box.

During the last spring many specimens of the small-mouthed salamander were taken about Irvington, Ind., and several of *A. punctatum*, which latter had not before been seen here. They were taken during March in ponds about which were pieces of fallen timber. On turning over a small log or a rail which lay

partly in and partly out of the water, one or more salamanders could often be found. In such situations they could obtain suitable food, and at night go forth to deposit their eggs. A little later, in the first days of April, they had left these situations, and one could be found only occasionally and away from the water. Later, none of either species could be found anywhere. The summer seems thus to be spent away from the water, burrowing about in the earth. Specimens of *microstomum* kept in the aquarium appeared, as warm weather came on, to be driven by an intense desire to leave the water. Occasionally one would swim about as if frantic; and so many were found dead that they were at length transferred into a box partially filled with earth. In this they remained quiet, at least during the daytime. The Amblystomas seem to be able to endure a good deal of drought, if necessary. A gentleman informed me that he had seen a specimen of the tiger salamander crawling about in a cornfield on a hot day in midsummer. On the other hand, this species seems to be capable of living all summer in the water.

During the winter, no doubt, many of these Amblystomas hide away under sticks and stones, and in the earth away from the water. I believe, however, that most of them betake themselves to the vicinity of the ponds, and remain either close about their borders or in them. I have several times received examples of both *A. microstomum* and *A. tigrinum* that had been taken in January and the early part of February from under the ice of ponds where boys were skating. On one occasion some of these were put into a tank of water; and this having frozen, they remained under the ice two or three days without injury. Some of these same specimens, which species I do not know, laid eggs on January 15.

Early in April of the present year, about thirty specimens of the small-mouthed salamader and eight or ten of the spotted salamander were put into a dry-goods box partly filled with earth. In order to separate the two species, a piece of bagging was tacked across the box. The box stood at least fourteen inches, and the bagging a foot, above the dirt. Every now and then a spotted fellow would be found on the wrong side of the wall.

Fearful lest some of them might escape, wire netting was laid over the box in such a way that it was thought that none could get out. Toward the last of June the dirt was carefully examined, and all of both species but eight specimens were gone. This will illustrate their ability to climb. They rely especially on climbing up the corners. I have watched them climb up the corners of a zinc box six inches high. They brace themselves on each side by pressing their feet against the walls. The tail is also brought into service, but when this was loosened the animal did not fall.

Mention has been made of the food of the older larvæ. The adults of the three species mentioned in this paper feed greedily on earthworms. When a worm is brought near the snout of a salamander, the latter may quietly observe it awhile; or if the worm is crawling away, he may follow it for awhile. Soon, however, there is a sudden forward movement, the jaws open, the broad tongue is protruded; and if the aim has been faulty, the jaws come together with a snap. If the worm has been caught, it is shaken as a dog shakes a snake; the part secured is held fast for awhile; then another quick snap is made and a little more of the worm is taken in. In this way a worm several inches long may be swallowed. It is amusing to watch two large salamanders try to swallow the same worm, one at each end.

It is probable that earthworms furnish the bulk of the diet of the Amblystomas; but they are ready to eat almost anything of an animal nature. A year ago I put a tiger salamander, eight inches long, into a large case with glass sides, where I could watch him. It was occasionally convenient to put other things into the same receptacle; and among them was a full-grown tree-frog, *Hyla versicolor*. Up to this time the salamander had not, so far as I knew, eaten anything for months. A few months afterward the salamander was found holding the frog by the foot, which on examination proved to be somewhat injured. During the day the frog kept out of the way of his persecutor; but next morning it was missing, while the salamander lay in his box of sand blinking serenely, and showing a stomach that protruded like that of the proverbial alderman. A cricket-frog and a large

caterpillar had previously disappeared somewhat mysteriously, and now their fate was explained. I have fed this specimen insects, fresh beef, and tadpoles. Once it swallowed a mass of three or four grape skins; but since he seemed to regard himself as no prodigal son in dire extremities, he refused to accept any more such favors. He swallowed with ease a half-grown wood-frog. A smaller frog had lain about and become dry and stiff. It was offered to the salamander, who began to swallow it but soon rejected it. A freshly-killed mouse was offered him and eagerly seized by the nose. He slowly swallowed it as far as the forelegs. Then a lack of confidence in himself seemed to seize him, he grew uneasy, dragged the mouse about, and at length succeeded in getting it out of his mouth. The mouse's head was covered with a sticky fluid, the secretion, no doubt, of the numerous glands that fill the tongue of the salamander. Dr. Robert Wiedersheim states that he found a shrew in the stomach of a specimen of *A. tigrinum* that he dissected. One day my large salamander seized a good-sized spotted salamander by the tail, and only with difficulty was he made to release his hold. The amphibians appear to swallow one another without much regard either to relative size or to the ties of consanguinity.

Reptiles at all periods of life, and amphibians after they have lost their gills, have been generally supposed to be wholly air-breathers; unless the skin may take some part in aerating the blood. Recently, however, the Profs. Gage [*Amer. Nat.*, XX., 233] have shown that the soft-shelled turtle enjoys an aquatic pharyngeal respiration, the mouth being filled and emptied by movements of the hyoidean apparatus. More recently [*Science*, VII., 395] they inform us that the newt, *Diemyctylus viridescens*, while under the water, both draws in and expels this element by the mouth. In this process the walls of the mouth and pharynx serve as a place of exchange between the oxygen of the water and the gases of the blood. The same authors have observed water to be taken into the mouth-cavity of *Cryptobranchus alleghaniensis*, and expelled, partly at least, through the gill-slit. This pharyngeal respiration may be readily observed in the three species of Amblystoma under consideration. In all of them, by

the dilation of the hyobranchial apparatus, streams of water are drawn in through the nostrils, and this water is then expelled at intervals by the mouth. By keeping the salamander in a glass vessel containing water that has in it fine floating particles, and using a lens, one may readily see all the phenomena mentioned. The animal will remain under the water several minutes, sometimes a quarter of an hour, breathing in this way. Then will occur motions indicating uneasiness; large bubbles of air may escape from the mouth, and the animal will come to the surface and take in fresh air. It may remain there for some time, or may again go to the bottom and stir about as if trying to conceal itself. The expulsion of the water through the mouth occurs in *microstomum* every eight to twelve seconds; in *tigrinum*, every five or six seconds; and in *punctatum*, every four or five seconds. It is probably due to this pharyngeal respiration that they are able to remain imprisoned for so long under the ice of ponds.

The Amblystomas shed the epidermal layer of the skin at frequent intervals. Whether this occurs oftener when they are in the water than in the earth, I do not know. The large specimen of *A. tigrinum* kept by me seemed to prefer to enter the water when about to exuviate. For some weeks during the past summer while he was confined to the water, he shed his skin about every week. The skin comes off in one almost untorn piece, and floats about in the water like a shadow of the original. It seems never to be swallowed, as it is said to be in the case of the newt.

The popular notion about these animals is that they are very poisonous. On the contrary they are perfectly harmless. Never but once have I succeeded in getting one of these animals even to attempt to bite. Once my large *tigrinum*, thinking that something was being offered him to eat, seized my little finger. His teeth could scarcely be felt. Even if they should penetrate the skin, there is no poison secreted that could enter the blood.

These animals are not averse to being handled. I have thought that the small-mouthed salamander likes to be rubbed along the back with the finger or a straw. When thus rubbed, I have seen it lift its tail high in the air and wave it to and fro in a ludicrous way.

All the tailed salamanders seem to dislike greatly to be turned over on their backs. They struggle violently to regain their normal position. While thus fastidious about being "right side up," some, at least, of the Amblystomas show extremely little intelligence in avoiding falls. They will crawl right off the hand or the table regardless of consequences. Very seldom have I seen my large *tigrinum* hesitate to walk off the surface on which he was resting. Even then had he been touched he would have rushed insanely over. Prof. Samuel Garman has observed that the tail of *A. punctatum* is somewhat prehensile, and is employed to prevent itself from falling. I have observed something of the same kind in this species, but not in the others. It may be permitted to notice here the highly developed prehensile power in the tail of *Diemyctylus*. Its rough flat tail is always ready to catch on objects, if need be. I have kept it hanging for a quarter of an hour on a slender penstock.

I have heard *A. microstomum* make a variety of sounds. One is a low piping sound uttered apparently just as the animal comes to the surface and emits air from its lungs. It may be heard at a distance of at least three or four feet. It may not be produced voluntarily. Sometimes the animal will poke its head out of the water and make a low clucking sound, accompanying it with a sudden movement of the throat. It also often produces a grating noise, as if by grinding its teeth together. It may be made to produce this noise by teasing it.